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Bellcomm, Inc.

QUARTERLY PROGRESS REPORT

October November December

1968

I. M. Ross
President

Bellcomm, Inc.

955 L'Enfant Plaza North, S. W. Washington, D. C. 20024

Report No. 69-101-1
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QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm, Inc., during the quarter ending December 31, 1968 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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APOLLO/SATURN SYSTEMS ENGINEERING
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Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was approved in early December and subsequently published by NASA. It included changes to: (1) provide for a lunar orbital CSM Operations Mission (C-Prime), (2) delete the earth orbital (E) mission, (3) include the lunar orbital (F) mission in the Lunar Mission Development phase, and (4) include a second manned lunar landing mission.

An outline of proposed mission assignments for the follow-on Lunar Exploration missions was presented to the Apollo Program Director on December 13.

Technical activities related to Apollo 8 (Mission C-Prime) included review of the detailed test objectives, the Preliminary and Final Launch and Flight Mission Rules, the Flight Plan, and the Mission Operations Report. Apollo 9 (Mission D) participation included a review of the Preliminary Flight Mission Rules.

Lunar Exploration Planning

Prior investigations of potential improvements in Apollo capability for lunar exploration are being refined and documented. Included are tradeoffs among lunar surface payload, returned payload and orbital payload; a reference profile for the proposed steep LM descent; and CSM performance studies for selected lunar exploration landing sites.

Vehicle Performance

Monthly preparation and delivery of Weight and Performance Reports continued. Presentations of weight and performance status were given at the monthly Apollo Program Office reviews.

Informal comments were provided to MSC regarding the "Revision I to 'Apollo Spacecraft Weight and Performance Definition' " which is in preparation. Upon receipt of the final version of this report, appropriate changes to the control weight and/or velocity budget sections of the Apollo Program Specification will be proposed.

Mission Analysis

An investigation of the factors affecting the probability of land impact by the CM following Launch Escape Vehicle (LEV) aborts was completed and documented.[1] The most important factors are the winds and the initial

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(1) The Probability of Land Landing After an LEV Abort, TM-68-2013-6, D. G. Estberg, December 31, 1968.

conditions of the LEV caused by the abort situation. Previous work in this area was based on worst case assumptions; this report combines the effects of the most significant factors statistically. The estimated probabilities of land landing using this method are significantly lower than the previous values. The sensitivity of this probability to selected parameters is also considered and methods for decreasing the probability of land impact are identified.

A study was completed concerning the ability of the Manned Space Flight Network to satisfy tracking and command requirements prior to Translunar Injection (TLI) on lunar missions.(2) The study concluded that the pre-TLI command pass timing determines the injection type preferred for coverage (Atlantic vs. Pacific). As the command pass time is moved closer to TLI, Atlantic injections are preferred.

A parametric analysis of the S-IVB stage slingshot (escape) maneuver by means of a cold residual propellant dump was completed and published.(3) The report gives information concerning the required dump maneuver attitude as a function of ΔV capability, time of application, and translunar trajectory inclination. It was concluded that a time controlled dump termination will be necessary to assure S-IVB escape because of the likelihood of large S-IVB residual propellant quantities on some missions.

An initial analysis of the possible use of the so-called hybrid translunar trajectory profile indicates that Pacific injections and, hence, daylight earth launches can be retained during the latter half of 1969 with a maximum SPS propellant requirement about 1500 lbs greater than for the optimum free return trajectory with Atlantic injection. Such an additional requirement is within capability if spacecraft inert weights remain near their present levels.

Trajectory Analysis

A presentation of trajectory and abort options was given at the C-Prime mission planning meeting at MSC on October 28.

A brief study of the trajectory aspects of short transearth flight times was conducted for the C-Prime mission.(4)

The Bellcomm Apollo Simulation Program (BCMASP) has been updated and improved. Some of the more significant changes were alterations to the

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(2) Pre-TLI Navigation and Command Passes for Lunar Missions, Memorandum for File, T. B. Hoekstra, November 29, 1968.

(3) Disposal of Spent S-IVB Stage on Lunar Missions, Memorandum for File, L. P. Gieseler, December 11, 1968.

(4) Trajectory Analysis Aspects of Short Transearth Flight Times for the C' Mission, Memorandum for File, T. L. Yang, November 14, 1968.

launch vehicle simulation to more accurately represent the current Saturn V vehicle timeline, an improvement in the accuracy of the earth potential model, and a provision for taking into account variations in I_{sp} with thrust for the LM Descent Propulsion System.

A model of the lunar potential function using point mass representation for lunar mass concentrations (mascons) has been developed for use with BCMASP. This model is available for studies related to mascons and for propagation of the state vector of vehicles in lunar orbit.

Guidance and Navigation Analysis

Studies of the LM descent phase were continued with emphasis on evaluating one and two-phase targeting schemes. The effects of lunar mass concentrations on LM descent are being studied.

A worst case error analysis of a scheme using a steep visibility phase (45°) for LM landings at science sites was conducted.(5) The scheme involves correction of navigational errors during the braking phase of the descent trajectory by identifying and marking landmarks whose positions relative to the landing site have been previously determined. It was concluded that velocity updatings should be available prior to high gate so that velocity errors could be nearly eliminated before the visibility phase. Subject to this, it was also concluded that the LM position errors at high gate could be reduced to less than 1,000 feet in each coordinate with a maximum fuel penalty of 60 fps.

Meetings were held with Langley Research Center (LaRC) and MSC to discuss an expanded utilization of the Lunar Landing Research Facility at LaRC for crew training and studies of the final phase of LM descent.

A study was made of Lunar Orbit Insertion (LOI) and Transearth Injection (TEI) burn errors due to center of gravity motion and thrust mistrim effects.(6) Satisfactory guidance and control performance was confirmed.

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(5) Simulation of Landmark Updating Navigation Scheme for LM Landing to Science Sites, TM-68-2015-6, G. L. Bush, I. Silberstein, November 26, 1968.

(6) Center of Gravity Motion and Initial SPS Motor Thrust Mistrim Effects on LOI and TEI Maneuvers, Memorandum for File, F. La Piana, October 15, 1968.

Support of the C-Prime mission included an analysis of the spacecraft attitude deviations during the LOI burn when the ΔV requirements are determined by the ground[7], a comparison of the MIT polynomial and the JPL tape used in calculating the position of the moon[8], an analysis of the first translunar midcourse correction for the C-Prime mission[9], and a presentation on the Colossus Command Module computer program used on the C-Prime mission.[10]

Work in the areas of navigation, tracking, and gravity modeling has continued. A joint LaRC/Bellcomm study resulted in the publication of a memorandum dealing with the lunar potential field.[11] An analysis was made of the use of the gravity gradient method of determining the local vertical on the moon in the presence of local mass concentrations.[12]

An analysis of CSM-LM rendezvous navigation showed that (1) VHF ranging used alone is relatively ineffective unless a non-diagonal covariance matrix is used to initialize the Kalman Filter, and that (2) navigation errors for the Primary Navigation, Guidance and Control System can be reduced if a non-diagonal covariance matrix is used.[13]

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(7) Spacecraft Attitude Variations During the C' Mission External ΔV LOI Maneuver, Memorandum for File, F. La Piana, December 9, 1968.

(8) Comparison of MIT 9th Degree Polynomial for Calculating the Position of the Moon with the JPL tapes, Memorandum for File, G. M. Cauwels, November 19, 1968.

(9) Analysis of the First Translunar Midcourse Correction for the Apollo C-Prime Mission, TM-68-2011-2, D. A. Corey, S. L. Levie, Jr., December 9, 1968.

(10) Colossus on C-Prime, Memorandum for File, W. G. Heffron, November 26, 1968.

(11) Bellcomm/LRC Limited Lunar Potential Field Determination for Apollo, Memorandum for File, B. G. Niedfeldt, J. T. Findlay, R. H. Tolson (LaRC), October 18, 1968.

(12) An Analysis of the Gravity Gradient Method for Determining the True Local Vertical on the Lunar Surface, Memorandum for File, A. J. Ferrari, December 11, 1968.

(13) Comparison of Sensor Performance and Initial Error Covariance Matrices for Rendezvous Navigation, TM-68-2014-6, W. O. Covington, December 18, 1968.

The approximations used in the Real Time Computer Complex (RTCC) for formulation of the range difference Doppler partial derivative for use in the orbit determination program were verified.[14]

Autodiagram, a program that automatically prints or plots a flow chart from the computer program source language, has been adapted to handle Apollo Guidance Computer programs. A presentation on this version of Autodiagram was given to MIT Instrumentation Laboratory. A copy of the program capable of running on MIT's IBM 360/75 was also delivered to MIT for their experimentation.

Flight Software Analysis

Bellcomm participation on the Apollo Spacecraft Software Configuration Control Board continued and Apollo flight software development and checkout was monitored.

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(14) Addition of Range Difference Observable to BCMTAP and Validation of RTCC Partials of this Data Type with Respect to State. Memorandum for File, J. T. Findlay, December 9, 1968.

Communications Systems

An analysis was made of the performance of the Apollo 8 television link using a station with a 30 foot diameter antenna as the receiving terminal.(15) The evaluation indicated that television can be received with an estimated margin of zero using the spacecraft omnidirectional antenna at a range of 6,000 nm. Using the spacecraft high gain antenna, the range is extended to 87,000 nm.

A study was made of the bandwidth requirements of the Apollo VHF ranging receiver.(16) It was found that even with worst case tolerance, the bandwidth of the existing design is adequate to pass the received ranging signal spectrum.

An evaluation of the S-IVB/IU Command and Communication System using an omnidirectional antenna showed that telemetry, range, and range rate data can be received at 35,000 nm when the vehicle is tracked by a MSFN station with an 85 foot diameter antenna.(17) Tracking data alone (range and range rate) is usable to lunar ranges.

Mathematical analysis of the Apollo Unified S-Band Communications System was continued. A revised model of the system was published which describes more accurately the operation of those communications modes involving ranging and gives the gain degradation that can be tolerated for all modes.(18)

Data on the experience obtained with the Apollo command system during three missions were summarized.(19)

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(15) Maximum Range for C' Mission Television to MSFN (30') Stations, Memorandum for File, N. W. Schroeder, December 18, 1968.

(16) Verification of Adequate Bandwidth in the Apollo VHF Ranging Receiver, Memorandum for File, K. H. Schmid, October 23, 1968.

(17) Performance of the Apollo Launch Vehicle (CCS-OMNI)/MSFN Communication Link, Memorandum for File, N. W. Schroeder, December 19, 1968.

(18) Communications Margins for Apollo Unified S-Band Links with Phase Modulation, TM-68-2034-17, N. W. Schroeder, December 31, 1968.

(19) Command Problems on AS-202, AS-501, and AS-204/LM-1 Missions, TM-68-2034-11, I. I. Rosenblum, December 31, 1968.

Launch Systems

Systems studies continued on problems in the area of hazardous egress. Problems associated with operations within and emergency egress from the SLA area were identified and assessed.[20] Informal technical notes to assist the Apollo Program Office in the conduct of the Launch Complex 39 Slidewire Design Certification Review were prepared.

A summary of wind restrictions and their effects on the launch of Apollo 8 was issued.[21]

Data pertinent to the launch preparations, launch countdown, and significant configuration differences for Apollo 8 were compiled and distributed to the Apollo Program Office staff.[22]

Studies of hold and recycle activities continued. An oral presentation discussing the significant hold capabilities and recycle requirements for the C-Prime and D missions was made to the Apollo Program Office staff. The CSM-103 systems having critical operating lifetimes were reviewed and a status report was prepared.[23] A study of the supercritical helium (SHe) system was continued to determine corrective measures to minimize its impact on recycle system activities.

Space Vehicle Systems

Analysis of the longitudinal vibration (POGO) of the Saturn V space vehicle continued. Final structural data for the AS-503 (CSM-103/LTA-8) configuration were obtained from MSFC and a complete set of nominal stability analyses and sensitivity studies was made. The results confirmed that the use of four prevalve accumulators in the inboard LOX suction lines adequately suppresses the 5 Hertz POGO instability as observed on Apollo 6 but small margins exist for higher frequency modes near the end of the S-IC powered flight. The results were reviewed with MSFC during POGO working group meetings and informal discussions.

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(20) SLA Egress Hazards and Provisions, Memorandum for File, W. O. Campbell, November 7, 1968.

(21) AS-503 Wind Restrictions, Memorandum for File, W. O. Campbell, December 17, 1968.

(22) AS-503/CSM-103 (Apollo 8) Launch Preparations, Launch Countdown, and Flight Sequence of Events, Memorandum for File, G. J. McPherson, Jr., November 22, 1968.

(23) Status of CSM-103 Critical Operating Life-Limited Items for the C' Mission, Memorandum for File, C. H. Eley, III, December 17, 1968.

A number of channels of flight data from the Apollo 4 and Apollo 6 missions were processed at Bell Telephone Laboratories, using a real-time spectrum analysis and display technique derived from visible speech research.[24] The results of this work were furnished to structural analysis groups at MSFC and MSC for their evaluation of its usefulness in diagnosis of such pheonomenon as POGO and vehicle structural dynamics.

The capability of the Apollo 8 and Apollo 9 spacecraft with respect to their expected launch environments was studied.[25] It was concluded that the Apollo 8 hardware was adequate assuming successful suppression of the S-IC POGO phenomenon, and that further analysis is needed to fully define the dynamic response of the LM on Apollo 9.

The Short Stack Static Tests at MSC (involving the SM, IU, SLA with LM test article, and S-IVB forward skirt) were assessed. Oral presentations and a test summary report were provided to the Apollo Program Office.[26]

Effort was continued to develop capability and techniques for consumables usage analysis.[27] The effect of consumables usage on CSM lunar orbit lifetime for the Apollo 8 mission was examined.[28] A capability for an additional week of contingency lunar orbit staytime was indicated.

The most probable causes, implications, and possible solutions for the high temperature anomaly in the No. 2 fuel cell condenser on the Apollo 7 mission were examined and reviewed for the Apollo Program Office.[29] The anomaly was probably caused by restricted bypass valve travel such that flow through the regenerative heat exchanger could not be completely cut off. No significant consequences resulted and fuel cell temperatures were always safely within limits.

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(24) Spectrum Analysis of Apollo 4 and Apollo 6 Data, Memorandum for File, J. Z. Menard, November 12, 1968.

(25) Apollo Spacecraft Dynamic Response to S-IC Thrust Oscillations and Corresponding Capability, AS-503 and AS-504 Missions, Memorandum for File, R. E. Hunter, November 26, 1968.

(26) Short Stack Static Test Summary, Memorandum for File, W. C. Brubaker, November 21, 1968.

(27) Apollo Consumables Report - LM Quick Look Capability, Memorandum for File, R. D. Raymond, December 30, 1968.

(28) Consumables Affecting Extended CSM Lifetime in Lunar Orbit, Memorandum for File, A. S. Haron, R. D. Raymond, December 31, 1968.

(29) Apollo 7 (CSM 101) - Preliminary Analysis of Fuel Cell No. 2, High Condenser Temperature Anomaly, Memorandum for File, S. S. Fineblum, November 6, 1968.

Available thermal data were used to develop an on-off cycling schedule that would permit intermittent operation of essential spacecraft systems, e.g., navigation, in the event that both cooling loops were lost in the lunar orbit or transearth phases of an Apollo mission.[30] An emergency procedure based on equipment cycling was suggested for the Apollo 8 mission.

Effort was continued on combustion analysis and the ignition and combustion properties of material in spacecraft atmospheres. A briefing on these activities was presented to personnel of the Office of Advance Research and Technology.[31]

Mission Assurance

Analyses of risks associated with various phases of Apollo missions were conducted. The effort involved assessment of specific issues, as well as participation in activities of the Crew Safety Board and intercenter panels, and included: (1) a review of tests and analyses pertaining to thermal conditions at the Saturn V engine compartment head shield in the event of an engine hardover, (2) an assessment of mission rules applicable to possible S-IVB LOX tank overpressurization[32], (3) a review of recent revisions to the Saturn V Emergency Detection System[33], and (4) participation in a review of abort landing recovery techniques.

A review and assessment of the relative risks associated with Apollo 8 mission options were conducted and the results were presented to the Apollo Program Director.

A study of manned space flight hazards and safety measures was completed.[34] The study developed a model of a manned space flight emergency and used it to define categories of hazards, emergencies and related safety measures. Events and conditions identified as hazards in five representative safety studies were used to compile hazards checklists in accordance with the defined categories.

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(30) Effect of Coolant Loop Failure on Performance of Essential Spacecraft Function, Memorandum for File, S. S. Fineblum, December 30, 1968.

(31) Briefing to OART on Our Activity in Combustion Analysis, Memorandum for File, M. V. Drickman, November 12, 1968.

(32) AS-503 S-IVB LOX Tank Overpressurization Problem, Memorandum for File, A. Bresnick, December 31, 1968.

(33) Revisions To The Saturn V Emergency Detection System, Memorandum for File, A. Bresnick, December 2, 1968.

(34) Manned Space Flight Systems—Classification of Hazards and Safety Measures, TM-68-2033-1, J. D. Richey, December 20, 1968.

A review was completed of the evolution and current status of provisions for Apollo crew safety covering: (1) the Apollo Program's approach to safety, (2) significant safety measures incorporated in Apollo, and (3) examples of redundant systems considered but not incorporated. The review developed material that was incorporated into a presentation to the Aerospace Safety Advisory Panel.

Surveyor Data Analysis

A series of reports on the interpretation of Surveyor landing dynamics data was concluded with a study involving the strain gage data.[35] A digital computer simulation of a landing on various model soils was used to estimate soil properties based on the fit of simulated to actual strain gage data. These soil properties agreed with those predicted earlier based on Surveyor footpad penetration data derived from TV pictures. It was concluded that a knowledge of the horizontal forces, which are not obtainable from the strain gage data, would be required to distinguish between certain soil mechanisms.

CSM Photography

Activities in support of the C-Prime mission included assistance in the preparation of the Mission Photo Plan and a study of lunar photographic targets for a launch delayed to January 1969.[36,37] Preparation for the C-Prime two-color photographic experiment continued with the development of experiment procedures.[38] Work in progress centers on investigating alternative methods of data reduction.

Additional effort supported experiments to assess an image motion compensation technique using the CSM Reaction Control System, to perform lunar photometric studies with zero phase photography obtained in the marial areas, and to measure lunar brightness using the existing spotmeter as an independent sensor.

The selection of recommended shutter settings for lunar surface photography on the Apollo 8 mission was completed and the data transfered to the Mapping Sciences Laboratory at MSC. A computer program for predicting film exposures was also completed and a copy provided to MSC. As a part of

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(35) Simulation of Surveyor Strain Gage Data, TM-68-1014-8, E. N. Shipley, October 9, 1968.

(36) Preparation of the C-Prime Mission Photo Plan, Memorandum for File, F. El-Baz, October 17, 1968.

(37) C' Mission - Targets-of-Opportunity Photographic Plan for the Month of January, 1969, Memorandum for File, F. El-Baz, December 6, 1968.

(38) 2 Color CSM Photographic Experiment Procedures, Memorandum for File, A. F. H. Goetz, November 26, 1968.

these efforts MSC and Bellcomm developed a revised estimate of the lunar farside albedo based upon Lunar Orbiter photography.[39] Work on the problems of calibration of the Apollo 8 cameras was begun.[40]

As part of the Apollo 8 Science Team, support was provided to the Lunar Operations Working Group during the Apollo 8 mission and the post-flight data analysis period.

Lunar Mission Studies

A study of the requirements and capabilities of the CSM to support lunar remote sensing experiments was completed.[41] The results indicate that photographic experiments can be conducted with low RCS fuel consumption using manually-assisted attitude control.

A preliminary evaluation was made of landing requirements that would be placed on an Extended Lunar Module (ELM) in visits to science sites.[42]

An analysis was made on the effect of several man-machine mission relationships on the operation of a Lunar Flying Unit.[43] Specific attention was given to lunar lighting and visibility, trajectory, profile, line-of-sight requirements and lunar surface interaction hazards. These were then applied to a sample exploration mission to Hyginus Rille and Crater, emphasizing the importance of site peculiarities. An evaluation of the lunar lighting effects on Lunar Flying Unit mission planning is being extended.

Lunar Science

A theoretical model developed to predict the interaction of the moon with the time-varying interplanetary magnetic field was used to derive techniques for the interpretation of Apollo Lunar Surface Experiment Package (ALSEP) magnetometer data. On the basis of the model, data from a single ALSEP magnetometer should be sufficient to calculate electrical conductivities of the

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(39) A Farside Albedo of 217, Memorandum for File, D. D. Lloyd, November 21, 1968.

(40) This was subsequently reported in Apollo 8 Camera Calibration Spectral Effects, TM-69-2015-1, H. W. Radin, January 13, 1969.

(41) CSM Attitude Control for Lunar Orbital Experiments, Memorandum for File, A. W. Zachar, November 15, 1968.

(42) Thoughts on LM Landing Requirements at Science Sites, Memorandum for File, I. Silberstein, December 18, 1968.

(43) Mission Aspects of Lunar Flying Unit Design and Operation, TM-68-2015-5, M. H. Kaplan, October 10, 1968.

lunar interior up to a maximum of about five mhos per meter. This appears to be adequate to discriminate between currently proposed hot and cold models for the lunar interior.(44)

The steady state lunar surface charge and potential distribution have been calculated from the condition of vanishing current to a surface element. It was shown that the balance between the two opposed dominant currents, due to collection of solar wind electrons and photoemission from the surface, is not sensitive to the detailed structure of the solar spectrum and shows moderate dependence on the photoemissive properties of the lunar surface. Plausible ranges for the latter suggest a range of 0.6 to 10.2 volts for the electrostatic potential at the subsolar point. The potential decreases toward the limb and never exceeds a volt at that point.(45)

The experimental phase of a cooperative study with the California Institute of Technology concerning infrared characteristics of Apollo sites has been completed. The data are being analyzed and prepared for publication. Preliminary results indicate no significant differences ($<1\%$), from 8 to 13 microns, among the five Apollo sites in spite of differences in apparent age and regolith thickness. This homogeneity is attributed to one or more of the following factors: uniform average composition; uniformly divided surface material at all sites; and masking surface alterations.

A paper on the "Classification of Lunar Rilles" was presented to the Geological Society of America annual meeting in Mexico City.(46) The morphological classification, based on Orbiter data, appears to divide lunar rilles into genetic categories as well and contributes to the study of these lunar features.

Studies on lunar and planetary slope distributions continued with the theoretical derivation of the root-mean-square slope over a finite span on a cratered surface.(47) The appropriate derived function was compared to a measured distribution determined by others from a Range VII map of Mare Cognitum. The fit between the data and the theoretical curve was good.

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(44) Lunar Response to the Time-Varying Interplanetary Magnetic Field and Application to the ALSEP Magnetometer Experiment, TR-68-710-7, J. L. Blank, W. R. Sill, November 8, 1968.

(45) Electrostatic Potential Distribution of the Sunlit Lunar Surface, Paper presented at the American Geophysical Union Meeting, San Francisco, California, December 2-5 1968; to be published in the proceedings. W. D. Grobman, J. L. Blank.

(46) Classification of Lunar Rilles, Paper presented to the Geological Society of America Annual Meeting, Mexico City, F. El-Baz, November 13, 1968.

(47) Variance of Lunar Slopes, TR-68-340-7, A. H. Marcus, November 27, 1968.

Apollo Surface Experiments

Evaluation of the ALSEP continued with attention focused on instrument status and on the development of the Early Apollo Surface Experiments Package (EASEP). Since the EASEP is highly constrained by cost and schedule considerations, work was started to look at ways to keep the package simple and perhaps substitute modified operational methods for hardware changes (e. g., dust protection).

Site Selection

Bellcomm chaired the third meeting of the Site Selection Subgroup of the Group for Lunar Exploration (GLEP) at Menlo Park, California.(48) The meeting resulted in recommendations of sites for lunar exploration missions. Priorities for the second mission were established as a function of the location of the first site visited. Particular attention was also given to selection of relocated or biased sites for the second mission. The value of Censorinus for a third mission was reemphasized.

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(48) GLEP Site Selection Subgroup Third Meeting - November 1968, Memorandum for File, F. El-Baz, December 19, 1968.

APOLLO APPLICATIONS SYSTEMS ENGINEERING
MISSION PLANNING

Weight Reporting

AAP Weight and Performance Reports for the months of October, November, and December were prepared, summarized for the AAP Director, and issued to Headquarters, KSC, MSC, and MSFC.

Flight Mechanics

Analyses of AAP rendezvous missions show that launch windows are much narrower and launch opportunities fewer with the orbit inclination increased to 35°.(49) Data were generated showing how payload capability varies with launch time during the launch window for both LM/ATM and CSM launches. Daily launch opportunities will not be available for the LM/ATM because it can be launched only when specific conditions on both the position of the Saturn I Workshop (SIWS) orbit plane and the position of the SIWS in its orbit are simultaneously satisfied. When these conditions are satisfied the LM/ATM must be launched within a few seconds of the nominal time. In general this necessitates launching the LM/ATM from a point out of the SIWS orbit plane and yaw steering during boost to insert the LM/ATM into the desired plane. The added fuel used in yaw steering results in a payload penalty.

For the CSM launches an SPS insertion burn is planned. Should an abort occur during this burn only the very limited SM/RCS capability is available to alter the trajectory toward a CM water landing area. Accordingly southerly CSM launch azimuths are preferred because of the greater safety offered by the corresponding minimum dwell time over Africa. Because time and propulsion are available for large phasing adjustments after launch, the CSM can be launched close to the optimum in-plane time, and very little payload loss is incurred for yaw steering.

Effort is continuing to determine possible guidance, navigation and tracking errors which could affect the AAP rendezvous maneuvers, particularly in the case of the unmanned LM/ATM rendezvous with the SIWS.

Computer simulations were made to determine the variation of the optimal S-IVB stage second mixture-ratio shift time with insertion orbit altitude.(50) The optimal burn duration at the second mixture-ratio was found to decrease

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(49) Payload Capability and Launch Windows for AAP Missions at 35° Inclination, Memorandum for File, W. L. Austin, I. Hirsch, K. E. Martersteck, December 20, 1968.

(50) Variation in S-IVB Optimal Second MR-Shift Time with Orbital Altitude for AAP, Memorandum for File, I. Hirsch, December 5, 1968.

almost linearly from 330 seconds for an 81 x 81 nm insertion orbit to 203 seconds for insertion into a 260 x 260 nm orbit. The design restriction that the second mixture-ratio shift occur no later than 280 seconds after S-IVB ignition requires a non-optimal shift time to be used for insertion into circular orbits below 148 nm. The resultant payload loss is, however, only 100 lbs at the lowest orbit, 81 nm.

MSFC-developed subroutines for the calculation of perturbations due to solar gravity, lunar gravity, and solar pressure have been added to the Bellcomm version of the MSFC Orbital Lifetime Program. (51) The predicted lifetimes of the AAP missions were found to be unaffected by the inclusion of these perturbations. However, the lifetime of a satellite with a low ballistic coefficient and flown in a higher orbit would be perturbed by these effects.

Mission Sequence

Detailed timelines for each crewman throughout the AAP-1/AAP-2 mission were constructed to determine the compatibility of experiment time requirements and available crew time. (52) All experiments currently assigned to the mission were scheduled. However, the amount of crew time remaining after experiments, meals, and sleep periods have been assigned was found to be marginal on several mission days. It was found possible to initiate all high priority medical experiments in the MDA by the end of the third mission day; all could be performed at least once by each crewman by the end of the fifth mission day. (53)

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(51) Additions to the MSFC Orbital Lifetime Program, Memorandum for File, R. C. Purkey, December 19, 1968.

(52) Experiment Scheduling for the AAP-1/AAP-2 Mission, Memorandum for File, D. J. Belz, December 11, 1968.

(53) Initiation Sequence for High-Priority Medical Experiments During the AAP-1/AAP-2 Mission, Memorandum for File, D. J. Belz, December 19, 1968.

CSM Modifications for AAP

Block II CSM spacecraft system modfications proposed for AAP and the requirements which generated the modifications were reviewed. [54] Of the twenty-six spacecraft subsystems, eighteen require modifications for AAP because of longer mission duration, increased mission support, docked attitude constraints, and a desire to save cost and weight. Ten subsystems require major modifications and the others only minor modifications, most of which are due to secondary effects.

LM-A Preliminary Design Review

Support was provided to the LM-A Preliminary Design Review (PDR) by pre-meeting review of the documentation package and the resultant generation of comments and recommendations which were introduced into the subsequent meetings. Specific Review Item Discrepancies (RID's) were submitted in the areas of ECS/Thermal, Instrumentation and Control, Guidance, Navigation and Control, and Crew Integration.

Alternate Configuration Studies

At the request of the Program Director, several alternate configurations were studied:

- A brief summary of the Block II CSM capability to support an AAP Workshop mission was provided to the Program Office. It was noted that the Block II CSM has the capability of supporting an AAP Cluster mission for approximately four days with some minor modifications for thermal control and Cluster pressurization. If the S-IVB workshop (OWS) is not pressurized (only the AM and MDA), the mission could be extended to approximately eight days. Reduction in crew size from three to two would have a neglible effect upon mission duration.

- The feasibility of accomplishing 28 and 56 day manned missions using a CSM that incorporates only modifications necessary for crew safety was investigated. [55,56] A mission support module would be required for each mission in lieu of the OWS/AM/MDA to provide additional work area and those

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(54) A Review of the Block II CM/SM Modifications Required for AAP, J. J. Gabrik, Memorandum for File, November 1, 1968.

(55) Minimum Apollo Applications Program, TM-68-1022-6, W. W. Hough, October 4, 1968.

(56) Orbit Selection and Propellant Requirements for a "Minimum Apollo Applications Program", Memorandum for File, W. L. Austin, December 20, 1968.

mission support items and consumables not carried by an Apollo CSM. The support module would be placed into orbit with a Saturn IB launch vehicle and followed by a CSM having only Apollo Block II propulsion capability. This mission would be feasible if the support module is flown in an elliptical orbit having altitude limits of 130 x 240 nm and an inclination of 29°. This provides an orbit lifetime greater than the required 60 days, RCS propellant consumption for rendezvous and backup deorbit within the Block II capacity, ample payload margins for both launches, and reasonable launch window freedom for the rendezvous. The ATM solar astronomy mission would be sacrificed in this minimum program.

- A study of system simplifications that would result if the OWS is left unpressurized in the baseline program indicated that only minor cost savings could be achieved. (57) Major simplifications result if the ATM is decoupled from the cluster and used only in decoupled mode with a CSM. (58) Because the active systems in the LM-A would not be required, it could be replaced by an MDA derivative that would decrease hardware development costs. The converse is not true—that is, elimination of decoupled mission capability would result in only minor savings in hardware development costs. (59)

Electrical Power Systems Studies

Aluminum was investigated as a replacement for copper in electrical wiring on AAP modules. (60) The change could save several hundred pounds of spacecraft weight, but leads to requirements for a complete new line of connectors and terminal devices. The change was not recommended.

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(57) AAP System Simplifications Resulting from an Unpressurized Workshop, Memorandum for File, J. J. Sakolosky, December 5, 1968.

(58) AAP System Simplifications Resulting from Decoupling the ATM from the Cluster, Memorandum for File, W. W. Hough, December 5, 1968.

(59) Elimination of Capability to Perform Decoupled ATM Mission, Memorandum for File, W. W. Hough, October 29, 1968.

(60) Use of Aluminum Wire on AAP as a Weight Saving Measure, Memorandum for File, B. W. Moss, October 18, 1968.

Environmental Control/Life Support Systems

Various molecular sieve configurations, which remove carbon dioxide from spacecraft cabin atmospheres, were examined and described.(61) In the case of AAP-2 it was recommended that the basic sieve should be backed up by a a second identical sieve.(62)

The life support systems used for EVA and suited IVA in AAP were reviewed.(63) It was concluded that the umbilical support plus a small, chest-mounted pressure control unit is the optimum system for AAP for all such activities, and no changes to the present baseline were recommended.

Thermal Systems Studies

Thermal control systems for the AAP CSM, ATM, AM and OWS were reviewed and described.(64) The Apollo Block II CSM thermal control systems were designed for the lunar mission and are being adapted for the AAP earth orbital missions. AAP has attitude constraints not required in Apollo and, compared to Apollo, these missions are cold-biased due to lower internal heat generation, the earth orbital environment, and shadowing during the backup astronomy mission.

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(61) Description of Molecular Sieve CO_2 Removal System, Memorandum for File, J. J. Sakolosky, December 20, 1968.

(62) Redundant Molecular Sieve Configuration for CO_2 Removal on AAP-2, Memorandum for File, J. J. Sakolosky, November 18, 1968.

(63) Review of EVA/IVA Life Support Equipment for AAP - ML Action Item 478, Memorandum for File, W. W. Hough, December 24, 1968.

(64) AAP CM-SM Thermal Control Systems, Memorandum for File, G. M. Yanizeski, November 4, 1968.

An integrated thermal control system proposed for the OWS and AM was reviewed. The results were presented to the Apollo Applications Program Director with the recommendation that the system be implemented. (65) The integrated thermal control system thermally isolates the OWS to reduce heat loss during cold conditions, and uses an AM active thermal control system of increased capacity to cool the OWS atmosphere during hot conditions.

A description of the Orbital Assembly environmental control system was presented to the Apollo Applications Program Director. (66) Descriptions of the thermal control liquid loop, the thermal control atmospheric loop, and the gas distribution and pressurization system were based on the latest design changes, including the OWS/AM integrated thermal control system, two molecular sieves, and the oxygen gas accumulator. Additional data were provided on the coolant properties, debris collection, and sonic flow limiter noise. (67)

Approaches to thermal analysis used in the six AAP spacecraft modules were reviewed, and the results were presented to the Apollo Applications Program Director. (68) Analyses by the centers and contractors are generally based on worst case conditions. All or nearly all parameters are biased to their maximum expected values and added to have an effect in one direction, either hot or cold. The treatment of OWS passive thermal behavior is an exception; these analyses use worst case or 3-sigma values for the separate parameters, but the effects on net heat gain or loss are root-sum-squared rather than simply totaled.

The use of high performance thermal insulation in the various AAP modules was studied to determine the effects of joints, seams, and penetrations; and to correlate theoretical and measured performance. (69) The reasons for locating the high performance insulation on the MDA between the meteoroid shield and the pressure shield, thereby introducing insulation penetrations,

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(65) Airlock Module/OWS Integrated Thermal Control System, Memorandum for File, J. E. Waldo, October 17, 1968.

(66) AAP Orbital Assembly Environmental Control Briefing, Memorandum for File, D. G. Miller, November 4, 1968.

(67) AAP Airlock Module Coolant, Debris Collection, and Sonic Flow Limiter Noise, Memorandum for File, D. G. Miller, December 5, 1968.

(68) AAP Thermal Analysis Presentation to ML, November 12, 1968, Memorandum for File, J. E. Waldo, November 19, 1968.

(69) Discussion of Theoretical and Measured Multi-Laminar Insulation Performance Data, Memorandum for File, J. W. Powers, December 16, 1968.

were reviewed and the design approach was affirmed. (70) Physical examination of the MDA high performance multi-layered insulation has shown the presence of fine polyurethane foam dust caused by the foam spacer manufacturing process. This dust can also be caused by space vehicle vibration. It was recommended that the possible effects of this dust on the ATM experiments be evaluated.

Attitude Control Studies

A study was made of the implications of having a non-redundant digital computer in the ATM Pointing Control System. (71) A manual backup exists for all functions performed by the digital computer except offset pointing recording, experiment pointing calibration, roll reference calculation, and implementation of the Control Moment Gyro (CMG) Distribution and Rotation laws. The last function is not essential. All other functions were determined to have a manual backup capability if the crew display or telemetry of the sun sensor offset angles and roll position mechanism angle can be made independent of the computer. However, it was felt that even with the added backup capability, the mission goals may be compromised by the numerous tasks resulting from a computer failure. A single crew member task simulation was recommended to provide a basis for determining whether or not a redundant digital computer is warranted.

Final reports were issued on the study of attitude stabilization of the AAP Cluster by passive CMG's as a possible backup to the active mode. (72, 73) It was determined that, with the present 2000 ft-lb-sec CMG's, satisfactory attitude hold of the Cluster cannot be obtained. The spin angular momentum would have to be approximately doubled before satisfactory performance could be obtained. Thus, the implementation of a passive CMG mode was not recommended for the ATM Pointing Control System.

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(70) Comments to Multiple Docking Adapter High Performance Insulation Design, Memorandum for File, J. W. Powers, December 20, 1968.

(71) ATM Digital Computer Functions and Backup Capability, Memorandum for File, W. Levidow, December 5, 1968.

(72) AAP-Cluster Stabilization by Passive Control Moment Gyros, TM-68-1022-7, J. W. Schindelin, October 25, 1968.

(73) On Space Vehicle Attitude Stabilization by Passive Control Moment Gyros, TM-68-1022-9, J. W. Schindelin, November 8, 1968.

In the interest of refining the model for aerodynamic torque used in Bellcomm's attitude control simulations, new analytic expressions were derived for the aerodynamic torque on a space vehicle configured as a finite cylinder with two flat solar panels.(74). The torque was evaluated taking into account the front, back, and end surfaces and the general direction of the air velocity relative to the vehicle.

A computer program was written to simulate crew motion disturbances that are described by random processes. The purpose of the simulation is to evaluate the performance of the ATM Pointing Control System under the action of random crew motion disturbances.(75,76)

Communications

A review of the preliminary requirements and criteria for voice communications for AAP Missions 1 through 4 resulted in recommendations to expand the requirements and criteria to include:

1. the AAP-3/AAP-4 back-up mission,

2. extravehicular and intravehicular astronaut activity,

3. the provision for sidetone to a crew member except when using the speaker-microphone subsystem,

4. the capability for the astronaut who is voice annotating the voice recorder during the operation of experiments to monitor the voice communications between the other two crew members and the Manned Space Flight Network, and

5. displays that indicate to the crew which audio channel is being recorded.(77)

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(74) Aerodynamic Torque on a Space Vehicle, TM-68-1022-10, E. Y. Yu, December 12, 1968.

(75) Digital Simulations of Random Crew Motion Disturbances, Memorandum for File, N. I. Kirkendall, December 31, 1968.

(76) The Simulation of a Stationary Gaussian Stochastic Process with Rational Spectral Density, TM-68-1033-7, J. L. Strand, December 31, 1968.

(77) Voice Communications Requirements and Criteria for AAP Missions 1 through 4, Memorandum For File, A. G. Weygand, November 15, 1968.

Caution and Warning

The existing caution and warning systems of the Command and Service Module and the Lunar Module have been reviewed and their adequacy for satisfying new Apollo Applications Program requirements has been evaluated.(78) New requirements for AAP that will impact the existing systems include an emergency subsystem, an automatic reset feature, and an astronaut adjustable analog measurement limit setting feature.

Launch Complex Deactivation

A review of Launch Complex (LC) 34 and LC 37 deactivation proceedings was conducted. Planning factors relative to the reactivation of these LC's to support AAP were summarized.(79)

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(78) Caution and Warning Systems of the CM/SM and LM for AAP, Memorandum For File, A. G. Weygand, November 20, 1968.

(79) LC-34 and LC-37 Deactivation, Memorandum for File, A. W. Starkey, November 29, 1968.

Experiments

The residual atmosphere at the operating altitude of the AAP Cluster has been examined for its effect on the ATM experiments. The White Light Coronagraph, Experiment S052, must be pointed 10° above the horizon to prevent sunlight scattered from the top of the earth's atmosphere from entering the instrument field of view. At this angle the sky brightness due to scattering along the line of sight is estimated to be an order of magnitude below the brightness of the corona under observation.[80] For solar observations in the ultraviolet region of the spectrum, Experiments S055 and S082A, there is absorbtion by the atoms and molecules of oxygen and nitrogen. When the sun is at the zenith of a 205 nm orbit, this absorbtion is about 1% but it increases to about 10% when the sun is 87° from the zenith.[81] The absorption of ultraviolet radiation by the thin atmosphere along the line of sight between the earth orbiting ATM and the sun limits the usable observation time on two of the ATM experiments.

Fourteen new and revised Experiment Implementation Plans for the medical experiments are being reviewed. Comments and suggestions pertaining to integration have been prepared and submitted on two of them, M151 - Time and Motion Study and M132 - Neurological Experiment.[82,83]

Consideration was directed toward the usefulness of flares and flashers to mark the location of the sodium cloud in the Sodium Cloud Photography Experiment S-051.[84] While the use of a high intensity flare was ruled out and the choice of an electrical flash discouraged, selection of a chemical flash which can provide millisecond flashes at any altitude was suggested as an adequate solution to the problem of identifying the cloud.

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(80) Influence of Sky Brightness and Reflected Sunlight on ATM Coronagraph Operation, Memorandum for File, T.C. Tweedie, Jr., October 14, 1968.

(81) Influence of Atmospheric Absorption of Solar Ultraviolet Radiation on ATM Operation, TM-68-1021-1, T.C. Tweedie, Jr., November 12, 1968.

(82) Review of Experiment Implementation Plan for Experiment M151 - Time and Motion Study, Memorandum for File, M.S. Feldman, November 26, 1968.

(83) Review of Experiment Implementation Plan for Experiment M132, Neurological Experiment - EEG, Memorandum for File, M.S. Feldman, December 16, 1968.

(84) Some Comments on the Utility of Flares and Flashers in the Sodium Cloud Photography Experiment S-051, Memorandum for File, C. Buffalano, October 28, 1968.

Radiation Studies

Spacecraft orbiting the earth with apogees below 700 nm encounter significant charged particle fluxes primarily in passage through the South Atlantic anomaly. A method for rapidly estimating the radiation dose received by astronauts in low earth orbit has been developed.[85] Daily radiation dose from trapped protons and electrons can be calculated by hand using the altitude of the orbit at the mean latitude of the anomaly region as the critical parameter. Results have been within a factor of two of computer calculations and in most cases were accurate to better than 50%.

Telescope Study

An engineering study of a proposed high resolution, segmented optics telescope resulted in the conclusion that the concept is not suitable for the low earth orbits of AAP. Orbits of 100,000 miles or more provide the most suitable environment, and even at these altitudes, fine pointing control requirements are beyond the present state of the art.[86]

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(85) Rapid Determination of Radiation Dose in Low Altitude Orbits, Memorandum for File, J.S. Ingley, October 28, 1968.

(86) Engineering Aspects of the Segmented Optics Telescope Concept, Memorandum for File, G. M. Anderson, R. J. Ravera, October 14, 1968.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING PROGRAM REQUIREMENTS

Five members of the Bellcomm technical staff were selected by NASA to be part of the Photo-interpretation Team on the 1971 Mariner Mars Orbiter. One member was named a Principal Investigator, and the other four members are Co-investigators. Their selection was made on the basis of a proposal to analyze television imagery from the 1971 mission for the effects of atmospheric haze which requires pre-flight experiment mission planning, real-time Planning during the nominal 90 day photographic mission in orbit about Mars, and data analysis, both during and after the mission.

A study was completed on the possibility of abiogenesis and extraterrestrial life based upon molecules other than the usual terrestrial biochemicals.[(87)] High cosmic abundance and small size were determined to be desirable features of atoms comprising the large molecules of living systems. It was concluded that hydrogen, carbon, nitrogen, and oxygen are necessary major components of biologically significant molecules, although some variation from the tertestrial biomolecules is possible under different pressure, temperature, and concentration conditions.

Only polar solvents composed of molecules that are resistant to oxidation and reduction would be possible as the media in which to carry on biological processes. Ammonia is a possible replacement for water under conditions where water is frozen but ammonia is a liquid.

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(87) On the Possibility of Exotic Biochemistries, TR-68-710-9, S. G. Schulman, December 17, 1968.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING
MISSION ANALYSIS

Earth Orbit

A set of studies of space station operations that focused on the role of man was completed. They provide an operational "point design" for planning purposes. After considering alternate space station concepts, a large, multidisciplinary manned Saturn V Workshop with a crew of six was selected for the study to provide: consistency with previous NASA studies; the opportunity to examine the role of man in relation to many disciplines; and the flexibility for application of portions of the study to more specialized station concepts.

An overview of the problem and guidelines for the other studies were developed.(88) It was assumed that the objective of the space station was to provide the capability to perform scientific and technological experiments easily and cheaply. A principal guideline for the studies was that experiment systems would be heavily automated to enhance the experimental return per astronaut man hour.

The experiment payload consisted of quasi independent packages which permitted the mission to be described by decoupled "sub-sequences." The subsequences were developed for the following disciplinary packages: Operations and Maintenance, Astronomy, Earth Looking, Biomedicine, Bioscience, and Personal Maintenance.

Since crew attention should be devoted to attaining the technical objectives of the mission, control of the operational systems, system performance monitoring and fault detection were automated(89). Crew members would be responsible for regular manual checks, inspections, replacement and repair of malfunctioning components.

The astronomy package consisted of parallel solar, stellar, and x-ray/gamma ray survey operations(90). The former used both automated and manned modes while the latter two were primarily automated. The principal manned activities were experiment deployment, maintenance and repair, data selection and editing, and active control of the solar sensors.

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(88) Introduction to a Study of Operations on a Multi-Disciplinary Space Station, TM-68-1011-11, G. T. Orrok, December 27, 1968.

(89) Operations and Maintenance Subsequence for a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-13, S. L. Penn, December 31, 1968.

(90) Astronomy Subsequence in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-5, N. Zill, December 27, 1968.

The earth looking experiments would perform ground programmed observations of the earth and its atmosphere[91]. Crew activities would include service, repair, performance checks, data monitoring, and special target selection.

Displays and controls for on-board manual operation were provided for both astronomical and earth looking experiments. The manual mode aided in maintenance activities and provided a back-up for failure of automated control. Specialist astronauts could use the manual mode for on-board operation of selected experiments.

The biomedical experiments would warn of impending behaviorial or physiological problems due to flight stresses. In addition, they: investigate the time course of man's physiological adaptation to zero gravity and post flight earth gravity conditions; test promising schemes to assist in this adaptation process; and provide the basis for predicting successful manned operation during extended, future missions.[92]

Bioscience activities included: lower animal and plant experiments; experiments on animals to study adaptability to prolonged zero-g conditions and to develop general surgical procedures for emergency use in space; and exobiology tests to develop advanced, sterile space laboratory techniques for examination of extraterrestrial material for life forms.[93]

The day to day activities (eating, sleeping, hygiene, exercise, rest and recreation, and housekeeping, etc.) and the scheduling considerations, whereby these activities impact the manpower available for experimental work, were studied.[94] The special conditions of space flight, including the closed ecological system, confinement, and weightlessness, are responsible for uncertainties in the requirements for personal maintenance, and at this time limit the time available for work to approximately eight hours per day.

A preliminary mission sequence plan was developed from the sub-seqquences to test the compatibility of the disciplines and provide insight into the feasibility of the assumed mission.[95] It was determined that, on the average,

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(91) Earth Looking Subsequence (Description and Operation) in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-8, W.W. Elam, December 27, 1968.

(92) Biomedicine Subsequence in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-6, R.E. McGaughy, December 27, 1968.

(93) Bioscience Subsequence in a Multi-Disciplinary Space Station, TM-68-1011-7, R.E. McGaughy, December 27, 1968.

(94) Personal Maintenance Subsequence for a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-10, S.L. Penn, M.A. Robinson, December 27, 1968.

(95) Mission Sequence Plan for a Multi-Disciplinary Earth Orbital Space Station - A Preliminary Report, TM-68-1011-9, S.L. Penn, December 27, 1968.

one crewman should be free of continuous task assignments so as to be available for tasks which arise irregularly from experiment related events such as solar flares, instrument/system related events such as equipment malfunctions, or crew illness. The mission sequence plan showed that a crew of six on a three shift day (with two men asleep and four awake at all times) permits a relatively continuous level of scheduled activity and flexibility for the performance of contingency tasks. Each eight hour shift had three periods of different astronaut availability: two hours of two man availability, four hours of four man availability, and two hours when no men were available for routine work.

The role of man on the space station was found to be varied and attractive.[96] Man was used on the station in the same way as on earth. More than half of the men's time was devoted to personal maintenance. A relatively small portion of working time is devoted to routine attention to experiment systems, with a similar portion available for response to problems as they arise. The bulk of the activity centers on certain areas such as biomedicine, solar astronomy and bioscience. An on-board specialist could use major facilities with some freedom to operate in a more exploratory manner than the automated modes permit.

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(96) <u>The Role of Man on a Multi-Disciplinary Space Station</u>, TM-68-1011-14, G. T. Orrok, December 30, 1968.

Life Support Subsystem

The use of ammonia and water as the atmospheric resupply to provide oxygen and nitrogen in a life support system was evaluated and determined to be feasible.(97) This concept works especially well with a Sabatier/Water Electrolysis oxygen recovery process which requires additional hydrogen to complete the reaction. Ammonia decomposition to obtain N_2 and H_2, and the subsequent purification, are well established processes. Water electrolysis is required for any closed loop oxygen recovery system and has been the subject of much NASA work. The performance is competitive with the Bosch Recovery System but has the major advantage of not requiring any cryogenic storage of O_2 and N_2 for makeup of leakage.

Mars Atmosphere Measurements

Two reports were completed which dealt with design requirements for density gages for use on atmospheric entry probes. One of the reports concluded that for a spherical density gage to make accurate measurements of the upper atmosphere density profile, the ratio of gas entrance (orifice) area to internal surface area should be about 0.01.(98) The other report showed that by using two free molecule density gages, one having a large response time and the other a small response time, both the density and the mean molecular weight of the upper atmosphere could be determined.(99) With only one density gage, a mass spectrometer would be necessary to provide similar information.

The feasibility of a proposed ionless mass spectrometer experiment was examined for its applicability on a Mars entry probe. It was concluded that this would not be a proper instrument for detailed component analysis of the atmosphere; but, because of its light weight, it might be carried to provide an independent measurement of mean molecular weight.

On-board Data Management

A presentation was given to the Mission Planning and Operations Office on inflight checkout and data management systems for a mid-1970's space station. This was an interim report on continuing efforts to define the functions and systems configuration of an on-board data management system.

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(97) Ammonia-Water Atmosphere Storage, Memorandum for File, R. Gorman, November 27, 1968.

(98) Design Criteria for an Upper Atmosphere Density Gage, Memorandum for File, R. N. Kostoff, October 16, 1968.

(99) Two Gage System for Upper Atmosphere Density Measurements, Memorandum for File, R. N. Kostoff, October 16, 1968.

MISSION OPERATIONS STUDIES

The performance of the KSC Operational Intercommunications System-Audio (OIS-A) was monitored during the countdown and launch of Apollo 7.(100) The quality of the basic OIS-A was good, with a few cases of crosstalk from other channels which might be noticeable but not objectionable. The performance of the OIS circuits as received at the Mission Control Center, Houston (MCC-H) was also monitored.(101) Differences in quality were noted which can be attributed to long-line effects and the multiple monitoring capability at MCC-H.

During early Apollo 7 KSC tests of the CSM downlink VHF voice signals, Bellcomm personnel participated in a number of special tests at MSC and KSC, and observed tests which led to the use of a wideband telemetry VHF receiver to feed the KSC circuits.

During the Apollo 7 mission, the voice communication links were monitored, including those with the spacecraft during the launch countdown and the orbital phases of the mission. Voice communication difficulties were experienced during the launch phase as a result of equipment malfunctions and procedural errors.(102) These were discussed with OMSF and GSFC personnel and changes to eliminate the difficulties were proposed. Observations made during the Apollo 8 launch indicated that the previously experienced problems had been eliminated.

An earlier study of the purposes and the history of flight control for manned space flight missions which had been presented orally was published.(103)

An investigation was started of the feasibility of using the 210 foot radio astronomy facility located at Parkes, New South Wales, Australia, for the first Apollo lunar landing mission. This facility, in combination with Goldstone, could provide television reception from the Lunar Module on the lunar surface with concurrent telemetry, voice and biomedical data without the use of the LM erectable antenna. It would require additional communications in Australia and between Australia and the United States.

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(100) Operational Intercommunication System Monitoring at KSC During Apollo 7 Launch, Memorandum for File, B. F. O'Brien, November 21, 1968.

(101) This was subsequently reported in KSC Operational Intercommunication System Monitoring at MCC During Apollo 7 Mission and Tests, Memorandum for File, J. E. Johnson, H. Kraus, January 14, 1969.

(102) Apollo 7 Launch Phase Air/Ground Voice Contact Analysis, Memorandum for File, L. A. Ferrara, December 30, 1968.

(103) Ground-Based Flight Control Activities During Manned Space Flight Missions, Memorandum for File, J. E. Johnson, H. Kraus, December 31, 1968.

An MSC proposal for reducing the cost of routing data from GSFC to the ALSEP control computer at MSC was reviewed.(104) No major disadvantages were seen to the proposed manual selection of either of two existing circuits into a single buffer terminal channeling ALSEP data into the IBM 360/50 control computer. This approach would be less expensive than the automatically switched, dual buffer terminal system originally proposed.

During the quarter, OMSF decided to deploy a modified ALSEP on the moon during the first lunar visit. A study was made to determine the impact of this decision on the ALSEP mission control facilities.(105) It was concluded that the system designed to support ALSEP would be more than adequate to support the modified ALSEP.

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(104) A Comparison of Alternate Approaches to Routing ALSEP Data Between GSFC and MSC, Memorandum for File, R. J. Pauly, October 22, 1968.

(105) Real Time Flight Support for a Contingency Science Mission Using a Modified ALSEP, Memorandum for File, R. J. Pauly, November 15, 1968.

SPECIAL TASK ENGINEERING STUDIES

Assistance in Certain Computer Operations and Related Activities

Task Order No. 12

During the period October 1 through December 31, NASA Headquarters usage of the UNIVAC 1108 computer was 58.26 hours. During October and November, Bellcomm honored a request by MSC for computer support in order to prepare for the Apollo 8 mission. The level of support was four hours a day during third shift five days a week, plus second and third shifts on Saturdays and Sundays. The total usage by MSC was 167.2 hours.

GENERAL MISSION ENGINEERING STUDIES

Long Range Planning

A comprehensive study in support of NASA Planning System activities for the FY70 Program and longer term plans was issued.(106) Costing methodologies used by the Program Category Working Groups were identified and discussed.(107)

As preparation for development of the Agency's FY71 Program and an Agency long-range plan, draft documents covering the following subjects were provided to the Chairman of the Planning Steering Group: (1) suggested NASA long-range program rationale and approach, and (2) possible guidelines for NASA Planning System activities in CY69.

Planetary Missions

An attractive Mercury mission with Venus swingby in 1978 was identified.(108) Some features of this mission are: 50 day launch window with injection velocity less than 15,400 fps from a 100 nm earth orbit, Venus passage distances between 1.5 and 2.5 Venus radii, and relatively low arrival velocities at Mercury after a 142 day trip. Study of this mission opportunity is continuing.

A brief summary of the characteristics of outer planet grand tour missions between 1976 and 1980 was prepared, based on a survey of the literature.(109) Launch velocity, Jupiter passage distance, trip duration, launch window, and guidance requirements are discussed.

An evaluation was made of the performance of a space storable (FLOX/CH_4) stage mounted atop a Titan IIIX/Centaur for outer planet grand tour missions.(110) It was shown that such a configuration can inject gross payloads of 1,700 to 2,700 lbs during the five opportunities occurring in 1976 through 1980.

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(106) <u>FY 1970 Program Planning Activities</u>, TR-68-103-5-1, J. E. Volonte, M. M. Cutler, J. P. Jamison, H. H. McAdams, W. J. McKune, C. P. Witze, November 1, 1968.

(107) <u>Costing Methodologies of the Program Category Working Groups in the 1968 NASA Planning System</u>, Memorandum for File, W. J. McKune, October 8, 1968.

(108) <u>Preliminary Results of an Attractive Earth-Venus-Mercury Mission in 1978</u>, Memorandum for File, A. A. VanderVeen, October 9, 1968.

(109) <u>Summary Description of Outer Planet Grand Tour Missions</u>, Memorandum for File, A. A. VanderVeen, December 26, 1968.

(110) <u>Space Storable Stage Atop the Titan IIIX (1205)/Centaur for Grand Tour Missions</u>, Memorandum for File, A. A. VanderVeen, December 5, 1968.

Venus Atmosphere

The apparent discrepancy was studied between the results of Venera 4, which measured atmosphere temperature and pressure as a function of altitude, and the results of Mariner V, which inferred values for these parameters from measurements of refractivity as a function of distance from Venus' center.(111) It is shown that this discrepancy may be a combination of true altitude errors in Venera 4 results and uncertainties in the estimated polarizibility of Venus' atmosphere used in the conversion of Mariner V results from refractivity to pressure and temperature. The possible refractivity contribution from unidentified highly polar substances that may exist but have not been identified may be large enough to account for a part of the apparent discrepancy, even if the number fraction of these substances is exceedingly small. Results of this study suggest definite ways for the resolution of the problem in future observations.

Correlation of earlier earth-based microwave and radar studies of Venus with extrapolations of the atmosphere profile from the recent results of Venera 4 and Mariner V, suggest the likelihood of an isothermal layer, at 645° K, extending to an altitude of 10 ± 4 km. This model confirms independently a value of 6054.5 ± 4.0 km for Venus' radius, and gives good agreement with the observed microwave interferometric results and brightness spectrum.(112)

Crew Requirements

A study was conducted of three modes of crew operation for long duration missions — one, in which at least one crew member is assigned full time to the control console; another, in which at least one crew member is awake and alert although not necessarily assigned to a specific console monitoring task; a third, in which all crew members are allowed to sleep at the same time. It was concluded that the second mode is an appropriate choice for missions of long duration.(113) The third mode also appears acceptable if the crew can be alerted by an audio signal in case of a system failure.

An analysis of the man-mission re-supply schedules that exist for extended missions was made.(114) It was shown that for a given mission the initial segments of the schedules which satisfy the mission constraints separate

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(111) A Review of Interpretations of the Mariner V-Venera 4 Discrepancy on the Venus Neutral Atmosphere, TM-68-1014-7, M. Luming, October 31, 1968.

(112) An Isothermal Lower Atmosphere for Venus?, Paper submitted for publication to "Science", W. Gale, M. Liwshitz, A. C. E. Sinclair.

(113) On the Mode of Spacecraft Operation of Long Duration Manned Missions, Memorandum for File, C. C. Ong, October 17, 1968.

(114) Launch-Man Sequencing for Extended Mission Effectiveness Study, TM-68-1033-6, L. D. Nelson, December 16, 1968.

all feasible schedules into only eleven different schedule types. Methods were developed to select the schedule types which maximize various arbitrary measures of effectiveness such as mission duration. These methods are applicable to other missions and constraint sets.

Failure Rate Analysis

Complex systems are subject to a breaking-in period during which failures occur at a relatively high rate. This rate declines steadily until a stable value is reached. Axioms that describe this breaking-in phenomena were presented together with an exploration of some of their elementary consequences.(115) Failure rate function estimates were used to delineate a procedure for estimating the onset of the stable period and the subsequent mean time between failures.

Slidell Computer Operations Study

The NASA study of the computing complex at Slidell, Louisiana, in which Bellcomm participated, was completed. It was concluded that because of the reduced activity levels anticipated for launch vehicle manufacture, certain activities within the computer complex could be consolidated with ensuing reduced cost. The results of the study were documented in "Slidell Computer Operations Study," published by office of Manned Space Flight, October 1968.

Spaceborne Computers

A survey was conducted of computer memories with greater than 10^7 bit capacities that might be available for use in space during the early to mid-1970's.(116) It was found that complementary Metal Oxide Semiconductor (MOS) memories and magnetic tape recorders will probably be dominant up to 10^8 bit capacity. At 10^8 bit capacity in early 1970's, MOS memory was estimated to require < 5 ft^3, < 200 lbs, and 10 watts, and a tape recorder to require < 0.1ft^3, < 10 lbs, and 10 watts.

Lunar Orbiter Data Analysis

A procedure for improving the visual quality of pictures using digital processing techniques was developed and tested. A computer tape was obtained from MSC which contained encoded video signals (64 levels or 6 binary digits per sample) received from Lunar Orbiter III. Using this information as an input to a computer that was programmed to simulate a spatial filter, the data was processed to compensate for Orbiter lens limitations and to reduce noise. It was verified that this technique can improve the visual quality and that further improvement could be achieved by finer quantization of the original video signal. It was also shown that interpolation techniques can be used to further improve

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(115) Decreasing Failure Rates and Some Related Statistical Tests, TM-68-1033-8, B. J. McCabe, November 13, 1968.

(116) Future Spaceborne Mass Memories, Memorandum for File, B. W. Kim, October 23, 1968.

visual quality of the processed pictures and to digitally enlarge selected parts of the pictures.

Western Test Range Docking Facility

An analysis of the requirements for and cost impact of docking facilities to handle large NASA launch vehicles at Western Test Range (WTR) concluded that docking facilities would be required for Saturn V or 260 inch Solid Rocket Motor (SRM) vehicles but that their cost would be a relatively small portion of the total cost of new launch facilities.[117] Further investigation showed that (1) water transportation is desirable for large diameter SRM's and is necessary for SRM's exceeding 156 inches in diameter, and (2) the total cost for construction and operation of a new Launch Complex at WTR, including water transportation facilities, is probably independent of the choice of SRM diameter.[118]

STAC-PSAC Winter Study

Papers were written in collaboration with STAC members in eight disciplinary areas in support of a STAC-PSAC Winter Study held at La Jolla, California, December 6-9. The subject addressed was "Uses of Manned Space Flight, 1975-1985". The areas covered were Astronomy, Physics, Life Sciences, Earth Sciences, Earth Applications, Materials and Processing in Space, the Lunar Program, and Space Operations. The papers defined objectives and programs that can be usefully pursued by the manned program in each discipline, assuming that substantial manned space capabilities will exist in the future including orbital stations and low cost space transportation.

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(117) WTR Dock Facilities for Future Launch Programs, Memorandum for File, G. W. Craft, December 9, 1968.

(118) This was subsequently reported in Trip Report - Western Test Range Solid Motor Facilities Discussion at McDonnell Douglas Corp. and the Aerospace Corporation, Los Angeles, Calif., December 12, 13, 1968, Memorandum for File, C. Bendersky, January 8, 1969.

ENGINEERING SUPPORT

Computing Facility

The UNIVAC 1108 computer operations were continued under the EXEC II batch processing system. Extensive testing and evaluation of the multiprogramming EXEC 8 system is being continued by Bellcomm and UNIVAC personnel. The major elements of EXEC 8 are functioning including the multiprogramming, time-sharing features with terminals and background batch jobs. The major points that must be resolved before EXEC 8 is acceptable are the throughput capabilities compared to the EXEC II system, and the reliability of the FORTRAN compiler and the FORTRAN library programs.

ADMINISTRATIVE

Contract and Financial

During December, negotiations with NASA concerning statement of work, estimated cost and fixed fee, man years, and related subjects were held for the seventh contract period, January 1 through December 31, 1969. An amendment to the contract covering these matters has been executed, effective January 1, 1969.

LIST OF REPORTS AND MEMORANDA

(List in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Minimum Apollo Applications Program, TM-68-1022-6, W. W. Hough	October 4, 1968
Costing Methodologies of the Program Category Working Groups in the 1968 NASA Planning System, Memorandum for File, W. J. McKune	October 8, 1968
Preliminary Results of an Attractive Earth-Venus-Mercury Mission in 1978, Memorandum for File, A. A. VanderVeen	October 9, 1968
Simulation of Surveyor Strain Gage Data, TM-68-1014-8, E. N. Shipley	October 9, 1968
Mission Aspects of Lunar Flying Unit Design and Operation, TM-68-2015-5, M. H. Kaplan	October 10, 1968
Engineering Aspects of the Segmented Optics Telescope Concept, Memorandum for File, G. M. Anderson, R. J. Ravera	October 14, 1968
Influence of Sky Brightness and Reflected Sunlight on ATM Coronagraph Operation, Memorandum for File, T. C. Tweedie, Jr.	October 14, 1968
Center of Gravity Motion and Initial SPS Motor Thrust Mistrim Effects on LOI and TEI Maneuvers, Memorandum for File, F. La Piana	October 15, 1968
Design Criteria for an Upper Atmosphere Density Gage, Memorandum for File, R. N. Kostoff	October 16, 1968
Two Gage System for Upper Atmosphere Density Measurements, Memorandum for File, R. N. Kostoff	October 16, 1968

TITLE	DATE
Airlock Module/OWS Integrated Thermal Control System, Memorandum for File, J. E. Waldo	October 17, 1968
On the Mode of Spacecraft Operation of Long Duration Manned Missions, Memorandum for File, C. C. Ong	October 17, 1968
Preparation of the C-Prime Mission Photo Plan, Memorandum for File, F. El-Baz	October 17, 1968
Bellcomm/LRC Limited Lunar Potential Field Determination For Apollo, Memorandum for File, J. T. Findlay, B. G. Niedfeldt, R. H. Tolson (LaRC)	October 18, 1968
Use of Aluminum Wire on AAP as a Weight Saving Measure, Memorandum for File, B. W. Moss	October 18, 1968
A Comparison of Alternate Approaches to Routing ALSEP Data Between GSFC and MSC, Memorandum for File, R. J. Pauly	October 22, 1968
Future Spaceborne Mass Memories, Memorandum for File, B. W. Kim	October 23, 1968
Verification of Adequate Bandwidth in the Apollo VHF Ranging Receiver, Memorandum for File, K. H. Schmid	October 23, 1968
AAP-Cluster Stabilization by Passive Control Moment Gyros, TM-68-1022-7, J. W. Schindelin	October 25, 1968
Rapid Determination of Radiation Dose in Low Altitude Orbits, Memorandum for File, J. S. Ingley	October 28, 1968
Some Comments on the Utility of Flares and Flashers in the Sodium Cloud Photography Experiment S-051, Memorandum for File, C. Buffalano	October 28, 1968
Elimination of Capability to Perform Decoupled ATM Mission, Memorandum for File, W. W. Hough	October 29, 1968
A Review of Interpretation of the Mariner V-Venera 4 Discrepancy on the Venus Neutral Atmosphere, TM-68-1014-7, M. Luming	October 31, 1968

TITLE	DATE
A Review of the Block II CM/SM Modifications Required for AAP, Memorandum for File, J. J. Gabrik	November 1, 1968
FY 1970 Program Planning Activities, TR-68-103-5-1, J. E. Volonte, M. M. Cutler J. P. Jamison, H. H. McAdams W. J. McKune, C. P. Witze	November 1, 1968
AAP CM-SM Thermal Control Systems, Memorandum for File, G. M. Yanizeski	November 4, 1968
AAP Orbital Assembly Environmental Control Briefing, Memorandum for File, D. G. Miller	November 4, 1968
Apollo 7 (CSM 101) - Preliminary Analysis of Fuel Cell No. 2, High Condenser Temperature Anomaly, Memorandum for File, S. S. Fineblum	November 6, 1968
Orbital Workshop Solar Array Presentation, Memorandum for File, G. M. Anderson	November 7, 1968
SLA Egress Hazards and Provisions, Memorandum for File, W. O. Campbell,	November 7, 1968
Lunar Response to the Time-Varying Interplanetary Magnetic Field and Application to the ALSEP Magnetometer Experiment, TR-68-710-7, W. R. Sill, J. L. Blank	November 8, 1968
On Space Vehicle Attitude Stabilization by Passive Control Moment Gyros, TM-68-1022-9, J. W. Schindelin	November 8, 1968
Briefing to OART on Our Activity in Combustion Analysis, Memorandum for File, M. V. Drickman	November 12, 1968
Influence of Atmospheric Absorption of Solar Ultraviolet Radiation on ATM Operation, TM-68-1021-1, T. C. Tweedie, Jr.	November 12, 1968
Spectrum Analysis of Apollo 4 and Apollo 6 Data, Memorandum for File, J. Z. Menard	November 12, 1968
Classification of Lunar Rilles, Paper presented to the Geological Society of America Annual Meeting, Mexico City, F. El-Baz	November 13, 1968

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Decreasing Failure Rates and Some Related Statistical Tests, TM-68-1033-8, B. J. McCabe	November 13, 1968
Trajectory Analysis Aspects of Short Transearth Flight Times for the C' Mission, Memorandum for File, T. L. Yang	November 14, 1968
CSM Attitude Control for Lunar Orbital Experiments, Memorandum for File, A. W. Zachar	November 15, 1968
Real Time Flight Support for a Contingency Science Mission Using a Modified ALSEP, Memorandum for File, R. J. Pauly	November 15, 1968
Voice Communications Requirements and Criteria for AAP Missions 1 through 4, Memorandum for File, A. G. Weygand	November 15, 1968
Redundant Molecular Sieve Configuration for CO_2 Removal on AAP-2, Memorandum for File, J. J. Sakolosky	November 18, 1968
AAP Thermal Analysis Presented to ML, November 12, 1968, Memorandum for File, J. E. Waldo	November 19, 1968
Comparison of MIT 9th Degree Polynomial for Calculating the Position of the Moon with the JPL Tapes, Memorandum for File, G. M. Cauwels	November 19, 1968
Caution and Warning Systems of the CM/SM and LM for AAP, Memorandum for File, A. G. Weygand	November 20, 1968
A Farside Albedo of .217, Memorandum for File, D. D. Lloyd	November 21, 1968
Operational Intercommunication System Monitoring at KSC During Apollo 7 Launch, Memorandum for File, B. F. O'Brien	November 21, 1968
Short Stack Static Test Summary, Memorandum for File, W. C. Brubaker	November 21, 1968
AS-503/CSM 103 (Apollo 8) Launch Preparations, Launch Countdown, and Flight Sequence of Events, Memorandum for File, G. J. McPherson, Jr.	November 22, 1968

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Apollo Spacecraft Dynamic Response to S-IC Thrust Oscillations and Corresponding Capability, AS-503 and AS-504 Missions, Memorandum for File, R. E. Hunter	November 26, 1968
Colossus on C-Prime, Memorandum for File, W. G. Heffron	November 26, 1968
2 Color CSM Photographic Experiment Procedures, Memorandum for File, A. F. H. Goetz	November 26, 1968
Review of Experiment Implementation Plan for Experiment MI51-Time and Motion Study, Memorandum for File, M. S. Feldman	November 26, 1968
Simulations of Landmark Updating Navigation Scheme for LM Landing to Science Sites, TM-68-2015-6, G. L. Bush, I. Silberstein	November 26, 1968
Ammonia-Water Atmosphere Storage, Memorandum for File, R. Gorman	November 27, 1968
Variance of Lunar Slopes, TR-68-340-7, A. H. Marcus	November 27, 1968
LC-34 and LC-37 Deactivation, Memorandum for File, A. W. Starkey	November 29, 1968
Pre-TLI Navigation and Command Passes for Lunar Missions, Memorandum for File, T. B. Hoekstra	November 29, 1968
Electrostatic Potential Distribution of the Sunlit Lunar Surface, Paper presented at the American Geophysical Union Meeting, San Francisco, California, W. D. Grobman, J. L. Blank	December 2-5, 1968 to be published in the Proceedings
Revisions To The Saturn V Emergency Detection System, Memorandum for File, A. Bresnick	December 2, 1968
AAP Airlock Module Coolant, Debris Collection, and Sonic Flow Limiter Noise, Memorandum for File, D. G. Miller	December 5, 1968
AAP System Simplifications Resulting From Decoupling The ATM From The Cluster, Memorandum for File, W. W. Hough	December 5, 1968

TITLE	DATE
AAP System Simplifications Resulting from an Unpressurized Workshop, Memorandum for File, J. J. Sakolosky	December 5, 1968
ATM Digital Computer Functions and Backup Capability, Memorandum for File, W. Levidow	December 5, 1968
Space Storable Stage Atop the Titan IIIX (1205)/ Centaur for Grand Tour Missions, Memorandum for File, A. A. VanderVeen	December 5, 1968
Variation in S-IVB Optimal Second MR-Shift Time with Orbital Altitude for AAP, Memorandum for File, I. Hirsch	December 5, 1968
C' Mission - Targets-of-Opportunity Photographic Plan for the Month of January, 1969, Memorandum for File, F. El-Baz	December 6, 1968
Addition of Range Difference Observable to BCMTAP and Validation of RTCC Partials of this Data Type with Respect to State, Memorandum for File, J. T. Findlay	December 9, 1968
Analysis of the First Translunar Midcourse Correction for the Apollo C' Mission, TM-68-2011-2, D. A. Corey, S. L. Levie, Jr.	December 9, 1968
Spacecraft Attitude Variations During the C' Mission External Δ V LOI Maneuver, Memorandum for File, F. La Piana	December 9, 1968
WTR Dock Facilities for Future Launch Programs, Memorandum for File, G. W. Craft	December 9, 1968
An Analysis of the Gravity Gradient Method for Determining the True Local Vertical on the Lunar Surface, Memorandum for File, A. J. Ferrari	December 11, 1968
Disposal of Spent S-IVB Stage on Lunar Missions, Memorandum for File, L. P. Gieseler	December 11, 1968
Experiment Scheduling for the AAP-1/AAP-2 Mission, Memorandum for File, D. J. Belz	December 11, 1968
Aerodynamic Torque on a Space Vehicle, TM-68-1022-10, E. Y. Yu	December 12, 1968

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Discussion of Theoretical and Measured Multi-Laminar Insulation Performance Data, Memorandum for File, J. W. Powers	December 16, 1968
Launch-Man Sequencing for Extended Mission Effectiveness Study, TM-68-1033-6, L. D. Nelson	December 16, 1968
Review of Experiment Implementation Plan for Experiment M132, Neurological Experiment-EEG, Memorandum for File, M. S. Feldman	December 16, 1968
AS-503 Wind Restrictions, Memorandum for File W. O. Campbell	December 17, 1968
On the Possibility of Exotic Biochemistries, TR-68-710-9, S. G. Schulman	December 17, 1968
Status of CSM-103 Critical Operating Life-Limited Items for the C' Mission, Memorandum for File, C. H. Eley III	December 17, 1968
Comparison of Sensor Performance and Initial Error Covariance Matrices for Rendezvous Navigation, TM-68-2014-6, W. O. Covington	December 18, 1968
Maximum Range for C' Mission Television to MSFN (30') Stations, Memorandum for File, N. W. Schroeder	December 18, 1968
Thought on LM Landing Requirements at Science Sites, Memorandum for File, I, Silberstein	December 18, 1968
Additions to the MSFC Orbital Lifetime Program, Memorandum for File, R. C. Purkey	December 19, 1968
GLEP Site Selection Subgroup Third Meeting - November, 1968, Memorandum for File, F. El-Baz	December 19, 1968
Initiation Sequence for High-Priority Medical Experiments During the AAP-1/AAP-2 Mission, Memorandum for File, D. J. Belz	December 19, 1968
Performance of the Apollo Launch Vehicle (CCS-OMNI)/MSFN Communication Link, Memorandum for File, N. W. Schroeder	December 19, 1968

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Comments to Multiple Docking Adapter High Performance Insulation Design, Memorandum for File, J. W. Powers	December 20, 1968
Description of Molecular Sieve CO_2 Removal System, Memorandum for File, J. J. Sakolosky	December 20, 1968
Manned Space Flight Systems--Classification of Hazards and Safety Measures, TM-68-2033-1, J. D. Richey	December 20, 1968
Orbit Selection and Propellant Requirements for a "Minimum Apollo Applications Program", Memorandum for File, W. L. Austin	December 20, 1968
Payload Capability and Launch Windows for AAP Missions at 35° Inclination, Memorandum for File, W. L. Austin, I. Hirsch, K. E. Martersteck	December 20, 1968
Review of EVA/IVA Life Support Equipment for AAP - ML Action Item 478, Memorandum for File, W. W. Hough	December 24, 1968
Summary Description of Outer Planet Grand Tour Missions, Memorandum for File, A. A. Vander-Veen	December 26, 1968
Astronomy Subsequence in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-5, N. Zill	December 27, 1968
Biomedicine Subsequence in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-6, R. E. McGaughy	December 27, 1968
Bioscience Subsequence in a Multi-Disciplinary Space Station, TM-68-1011-7, R. E. McGaughy	December 27, 1968
Earth Looking Subsequence (Description and Operation) in a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-8, W. W. Elam	December 27, 1968
Introduction to a Study of Operations on a Multi-Disciplinary Space Station, TM-68-1011-11, G. T. Orrok	December 27, 1968
Mission Sequence Plan for a Multi-Disciplinary Earth Orbital Space Station - A Preliminary Report, TM-68-1011-9, S. L. Penn	December 27, 1968

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Personal Maintenance Subsequence for a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-10, S. L. Penn, M. A. Robinson	December 27, 1968
The Role of Man on a Multi-Disciplinary Space Station, TM-68-1011-14, G. T. Orrok	December 30, 1968
Apollo Consumables Report - LM Quick Look Capability, Memorandum for File, R. D. Raymond	December 30, 1968
Apollo 7 Launch Phase Air/Ground Voice Contact Analysis, Memorandum for File, L. A. Ferrara	December 30, 1968
Effect of Coolant Loop Failure on Performance of Essential Spacecraft Function, Memorandum for File, S. S. Fineblum	December 30, 1968
AS-503 S-IVB LOX Tank Overpressurization Problem, Memorandum for File, A. Bresnick	December 31, 1968
Command Problems on AS-202, AS-501 and AS-204/LM-1 Missions, TM-68-2034-11 I. I. Rosenblum	December 31, 1968
Communications Margins for Apollo Unified S-Band Links with Phase Modulation, TM-68-2034-17, N. W. Schroeder	December 31, 1968
Consumables Affecting Extended CSM Lifetime in Lunar Orbit, Memorandum for File, A. S. Haron, R. D. Raymond	December 31, 1968
Digital Simulations of Random Crew Motion Disturbances, Memorandum for File, N. I. Kirkendall	December 31, 1968
Ground-Based Flight Control Activities During Manned Space Flight Missions, Memorandum for File, J. E. Johnson, H. Kraus	December 31, 1968
Operations and Maintenance Subsequence for a Multi-Disciplinary Earth Orbital Space Station, TM-68-1011-13, S. L. Penn	December 31, 1968
The Probability of Land Landing After an LEV Abort, TM-68-2013-6, D. G. Estberg	December 31, 1968

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The Simulation of a Stationary Gaussian Stochastic Process with Rational Spectral Density, TM-68-1033-7, J. L. Strand	December 31, 1968
Trip Report - Western Test Range Solid Motor Facilities Discussion at McDonnell Douglas Corp. and the Aerospace Corporation, Los Angles, Calif., December 12, 13, 1968, Memorandum for File, C. Bendersky,	January 8, 1969
Apollo 8 Camera Calibration - Spectral Effects, TM-69-2015-1, H. W. Radin	January 13, 1969
KSC Operational Intercommunication System Monitoring at MCC During Apollo 7 Mission and Tests, Memorandum for File, J. E. Johnson, H. Kraus	January 14, 1969
An Isothermal Lower Atmosphere for Venus Paper submitted for publication to "Science", W. Gale, M. Liwshitz, A. C. E. Sinclair	To be published